

This Page Is Inserted by IFW Operations  
and is not a part of the Official Record

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning documents *will not* correct images,  
please do not report the images to the  
Image Problem Mailbox.**

(19) World Intellectual Property Organization  
International Bureau



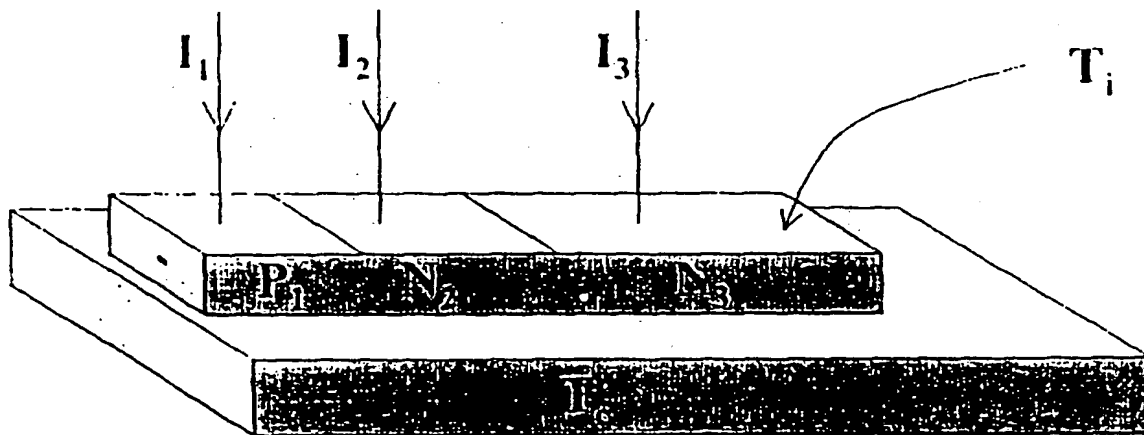
(43) International Publication Date  
11 October 2001 (11.10.2001)

PCT

(10) International Publication Number  
**WO 01/76029 A1**

- (51) International Patent Classification<sup>7</sup>: H01S 5/0687
- (21) International Application Number: PCT/SE01/00479
- (22) International Filing Date: 7 March 2001 (07.03.2001)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
0001251-8 5 April 2000 (05.04.2000) SE
- (71) Applicant (for all designated States except US): ALTI-TUN AB [SE/SE]; Box 911, S-175 29 Järfälla (SE).
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): WESSTRÖM, Jan-Olof [SE/SE]; Inedalsgatan 19, S-112 33 Stockholm (SE).
- (74) Agents: ÖRTENBLAD, Bertil et al.; Noréns Patentbyrå AB, P.O. Box 10198, S-100 55 Stockholm (SE).
- (81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- Published:  
— with international search report
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD FOR FREQUENCY AND MODE STABILISATION OF A TUNEABLE LASER THAT HAS AT LEAST THREE SECTIONS



(57) Abstract: A method for frequency and mode stabilisation of a tuneable laser that has at least three sections, such as a Bragg laser or GCSR laser, where measurable magnitudes are measured and the laser has been characterised with respect to a number of operation points, and where the values of the measurable magnitudes are stored in a microprocessor or corresponding device. The invention is characterised in that the values of one or more of the measurable magnitudes (E) are caused to be non-extreme values; in that the measurable magnitudes include back power in addition to front power and frequency; and in that control currents (I1, I2, I3; I1, I2, I3, I4) for the gain section (P1), the phase section (N2; N3) and the reflector section (N3; N4) respectively of said laser, and when applicable also for the coupler section (N2) of said laser, are caused to be controlled on the basis of the measured values of said measurable magnitudes while keeping both the front power and back power constant.

WO 01/76029 A1

METHOD FOR FREQUENCY AND MODE STABILISATION OF A TUNEABLE  
LASER THAT HAS AT LEAST THREE SECTIONS

5 The present invention relates to a method of stabilising  
frequency and mode of a tuneable laser.

10 Tuneable semiconductor lasers include several different  
sections through which current is injected, these sections  
typically being three or four in number. The wavelength,  
power and mode purity of the lasers can be controlled by  
adjusting the current in the different sections. Mode purity  
implies that the laser is at an operation point, i.e. in a  
combination of the three or four injected drive currents that  
is characterised by the laser being distanced from a  
15 combination of the drive currents with which mode jumps occur  
and where lasering is stable and sidemode suppression is  
high.

20 Special requirements are required for different applications  
with respect to controlling wavelength. In the case of  
telecommunications applications, it is necessary that the  
laser is able to retain its wavelength to a very high degree  
of accuracy and over a long period of time, after having set  
the drive currents and the temperature. A typical accuracy is  
25 0.01 nanometer while a typical time period is 20 years.

30 In order to be able to control the laser, it is necessary to  
map the behaviour of the laser as a function of the different  
drive currents. This is necessary after manufacture but prior  
to using the laser.

It is also highly desirable to be able to lock the wavelength of a laser and have control over the mode in which the laser operates, so that said laser will operate as intended over a long period of time. By mode control is meant optimisation of the laser operation point in operation, either continuously or at regular intervals, so as to eliminate the risk of a mode jump to some other cavity mode. Furthermore, it would be very beneficial if lasers could be automatically compensated for degradation in operation.

10

Several methods of mobilising the frequency and mode of a tuneable laser are known to the art. Several of these methods involve adjusting a current through a laser section so that the laser will continue to lase at the right frequency, while adjusting the currents through other laser sections while seeking a maximum or minimum in some measurable function, such as the laser output power.

20

Swedish Patent Specification No. 9900537-3 describes a method of wavelength locking and mode monitoring a tuneable laser. In this method, as with other methods, the laser is controlled at an operation point which lies at an extreme point on the measurable functions.

25

Certain functions have no usable extreme point. For instance, the output power of a GCSR laser may have a sawtooth configuration. Consequently, no extreme value is reached before the laser jumps to the next mode.

30

It is often found that the best laser operation point does not lie on a usable extreme point of the measurable

functions, since such points often mean that the laser operates close to a mode jump.

Consequently, it is beneficial to lock control of the laser at, for instance, a given gradient of a curve, such as the curve of the output power as a function of reflector current. However, this causes a problem when the laser degrades, since such curves become "stretched" as the laser ages, therewith changing the gradient of the curve.

The present invention solves the problem associated with the use of values that are not the extreme values of measurable magnitudes for controlling a laser that degrades.

The present invention thus relates to a method of frequency and mode stabilising a tuneable laser that has at least three sections, such as a Bragg laser or a GCSR laser, where measurable magnitudes are measured; said laser having been characterised with respect to a number of operation points, wherein the values of the measurable magnitudes are stored in a microprocessor or corresponding device, and wherein the method is characterised by causing the values of one or more of the measurable magnitudes to be non-extreme values; and is further characterised in that the measurable magnitudes include the back power in addition to the front power and frequency; and in that control currents for the gain section, phase section and reflector section of the laser, and when applicable also the coupler section, are caused to be controlled on the basis of the values measured for the measurable magnitudes while keeping both the front power and the back power constant.

The invention will now be described in more detail with reference to exemplifying embodiments of the invention and also with reference to the accompanying drawings, in which

- Figure 1 is a schematic illustration of a laser that includes three sections;

- Figure 2 is a block diagram;

- Figure 3 is a diagram showing front power as a function of reflector stream in a DBR laser; and

- Figure 4 is a schematic illustration of a laser that has four sections.

Figure 1 shows a laser that has three sections P1, N2 and N3 on a carrier TC, where currents I1, I2 and I3 are injected into respective sections.

A laser is controlled by control variables in the form of currents that are injected into the different sections of the laser or in the form of the voltage applied across different sections, and also the carrier temperature T. These variables control a number of laser internal variables, of which the charge carrier density is the most essential. Temperature is ignored in the following, although it can be treated in the same way as the control currents I.

Directly measurable magnitudes, such as the output power and the frequency of the laser and sidemode suppression are all functions of said internal variables.

Only certain combinations of the internal variables result in desired laser properties, such as desired frequency, high sidemode suppression, desired output power, and sufficient distance to mode jumps.

When characterising the laser, good operation points are chosen at different frequencies and these frequencies stored in the form of different currents injected into the various laser sections.

5

The relationship between the internal variables and the control variables changes as the laser degrades.

10

However, it is not possible to measure the internal variables.

15

Almost all measurable variables are functions of the internal variables, wherewith the operation point of the laser will be displaced as a result of said laser degradation when the control currents are used to control the laser by holding said currents constant.

20

The present invention relates to a method of stabilising frequency and mode in a tuneable laser that has at least three sections, such as a Bragg laser or GCSR laser, where measurable magnitudes are measured, wherein said laser has been characterised with respect to a number of operation points and wherein the values of the measurable magnitudes are stored in a microprocessor or corresponding device.

25

A Bragg laser has only three sections, these being a gain section (P), phase section (N2) and reflector section (N3). It is easy to measure front power, back power and transmitted frequency.

30

If the front power becomes too low, it is reasonable to increase the current to the gain section. If the frequency

becomes too low, it is reasonable to increase the current to both tuning sections.

Expressed simply, there are several operation points that give the same output power and the same frequency but different back powers. Such an operation point can lie closer to a mode jump in another operation point. Consequently, it will not suffice to control the laser with front power and frequency, since further relationships will be required.

10

Figure 3 is a diagram that illustrates the front power of a laser as a function of reflector current in a DBR laser. It will be seen from Figure 3 that the front power varies significantly with respect to the reflector current.

15

According to the invention, there is chosen between the extreme values of the curve an operation point that is far away from points at which mode jumps occur.

20

It is also proposed in accordance with the invention that the values of one or more of the measurable magnitudes are caused to be non-extreme values, where the measurable magnitudes include back power in addition to front power and frequency. The control currents for the gain section, phase section and reflector section of the laser are caused to be controlled on the basis of the measured values of said measurable magnitudes.

25

30

The invention is thus based on the realisation that in the case of a laser that has at least three sections the back power and the front power can vary independently of each other, and on the realisation that degradation of the laser



can be compensated for by controlling the different laser sections such as to retain the chosen values of both front power and back power, despite non-extreme values being used for this control. This compensation means that the internal variables, or charge carrier density, are/is kept constant in the respective various sections of the laser.

The same applies to a laser that has four sections, such as a GCSR laser. This latter laser has a gain section (P1), a coupler section (N2), a phase section (N3) and a reflector section (N4).

The measurable magnitudes are front power, back power, frequency and spontaneous emission from the coupler section, the phase section and the reflector section. The spontaneous emission can be measured in a known manner at the front mirror, back mirror or on one side of the laser.

The spontaneous emission is measured by filtering out the wavelength of the laser light.

The invention also relates to the frequency and mode stabilisation of a tuneable laser that includes four sections, such as a GCSR laser, wherein the measurable magnitudes are comprised of the back power and a fourth magnitude in addition to the front power and the frequency of the laser. The fourth magnitude is the so-called spontaneous emission from the coupler section, the phase section and the reflector section. Control currents I1, I2, I3, I4 for the gain section P1, coupler section N2, phase section N3, and reflector section N4 respectively of said laser are caused to be controlled on the basis of the values measured in respect

of the measurable magnitudes, wherein the coupler section or the reflector section or both sections are controlled on the basis of the spontaneous emission.

5 Figure 2 illustrates a control circuit and devices used in characterising a laser. In operation, the laser A is connected to a microprocessor B and to variable measuring units C. The laser A is controlled by the microprocessor B, which controls and adjusts the control currents D to the  
10 laser sections. These adjustments are based on measurements E from the measuring units C. The microprocessor B compares data E' received from the measuring units C with predetermined values that were obtained when characterising the laser, these values being found stored in the  
15 microprocessor. Upon completion of the comparison, the microprocessor makes any adjustments necessary to the control currents to the different laser sections.

In characterising the laser, the light H emitted is detected,  
20 for instance with respect to its power, sidemode suppression, frequency, etc., by analysing the light in a measuring instrument G that may include a spectrum analyser and a wavelength meter. The measured values I are sent to a computer F which is programmed to select optimal operation  
25 points, these operation points J then being transmitted to the microprocessor B.

It will thus be apparent that the present invention not only eliminates the extension of relationships as a result of  
30 degradation, but also provides a sufficient number of control variables to cause the laser to operate in the same operation point as that chosen when characterising the laser.

It will also be apparent that the present invention solves the problem mentioned in the introduction.

5 Although the invention has been described above with reference to a number of exemplifying embodiments, it will be understood that the invention can be applied with lasers other than Bragg lasers and GCSR lasers.

10 It will therefore be understood that the invention is not restricted to these described and illustrated embodiments thereof, since variations can be made within the scope of the following Claims.

CLAIMS

1. A method for frequency and mode stabilisation of a tuneable laser that has at least three sections, such as a Bragg laser or GCSR laser, where measurable magnitudes are measured and the laser has been characterised with respect to a number of operation points, and where the values of the measurable magnitudes are stored in a microprocessor or corresponding device, characterised in that the values of one or more of the measurable magnitudes (E) are caused to be non-extreme values; in that the measurable magnitudes include back power in addition to front power and frequency; and in that control currents (I1, I2, I3; I1, I2, I3, I4) for the gain section (P1), the phase section (N2; N3) and the reflector section (N3; N4) respectively of said laser, and when applicable also the coupler section (N2) of said laser, are caused to be controlled on the basis of the measured values of said measurable magnitudes while keeping both the front power and back power constant.

20

2. A method according to Claim 1 for frequency and mode stabilisation of a tuneable laser that has three sections, such as a Bragg laser, characterised in that the measurable magnitudes include back power in addition to front power and frequency; and in that respective control currents (I1, I2, I3) for the gain section (P1), the phase section (N2) and the reflector section (N3) of the laser are caused to be controlled on the basis of the measured values of said measurable magnitudes.

25

30

3. A method according to Claim 1 for frequency and mode stabilisation of a tuneable laser that has four sections,

such as a GCSR laser, characterised in that the measurable magnitudes include back power and a fourth magnitude in addition to front power and frequency; in that the fourth magnitude is spontaneous emission from the coupler section, the phase section and the reflector section; and in that  
5     respective control currents ( $I_1$ ,  $I_2$ ,  $I_3$ ,  $I_4$ ) for the gain section ( $P_1$ ), the coupler section ( $N_2$ ), the phase section ( $N_3$ ) and the reflector section ( $N_4$ ) of the laser are caused to be controlled on the basis of the measured values of the  
10    measurable magnitudes, wherein the coupler section or the reflector section or both of said sections are controlled on the basis of the spontaneous emission.

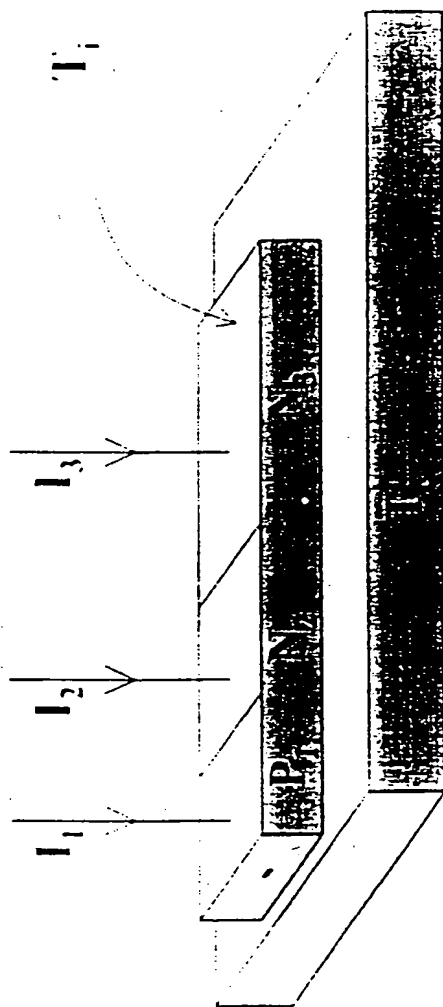


Figure 1

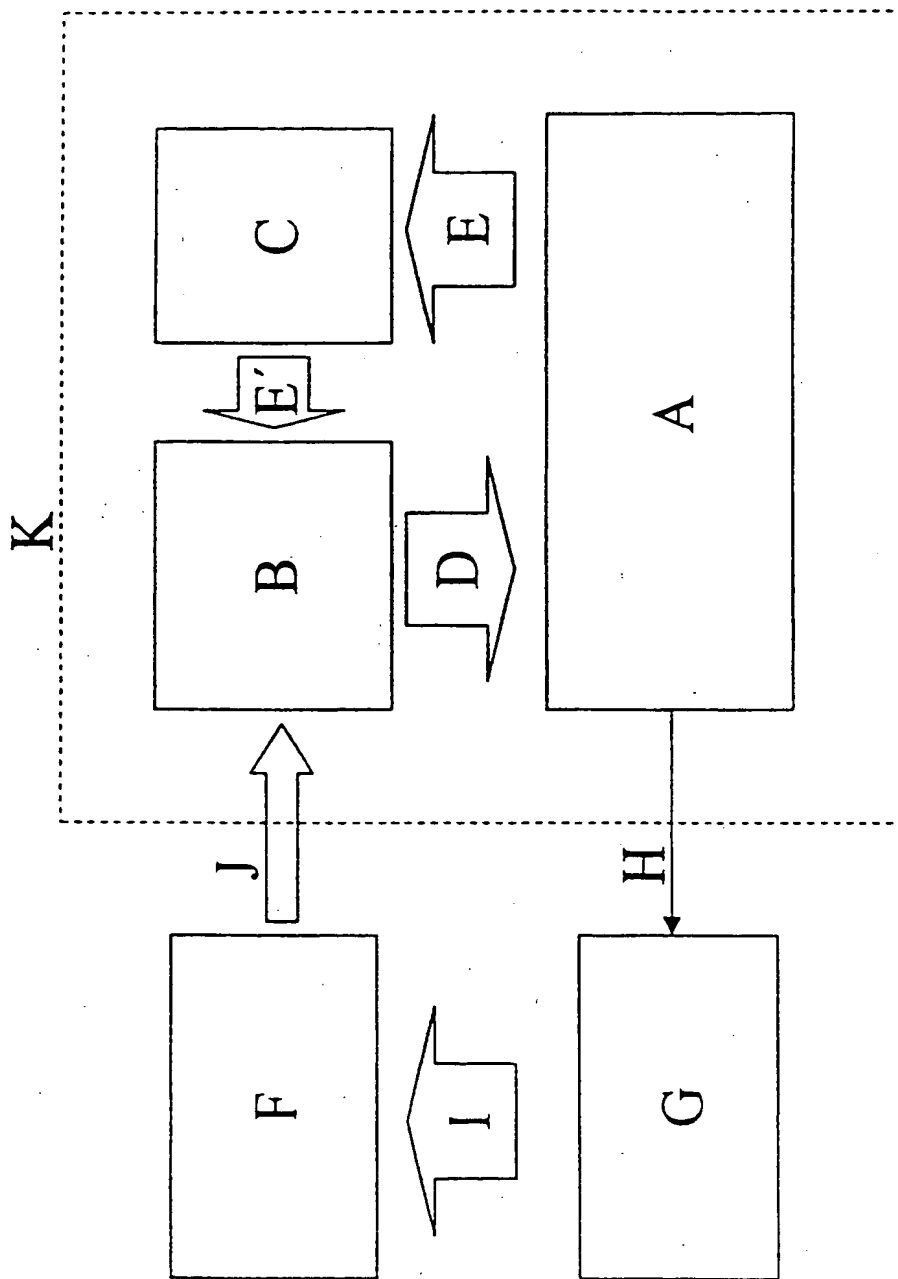


Figure 2

3/4

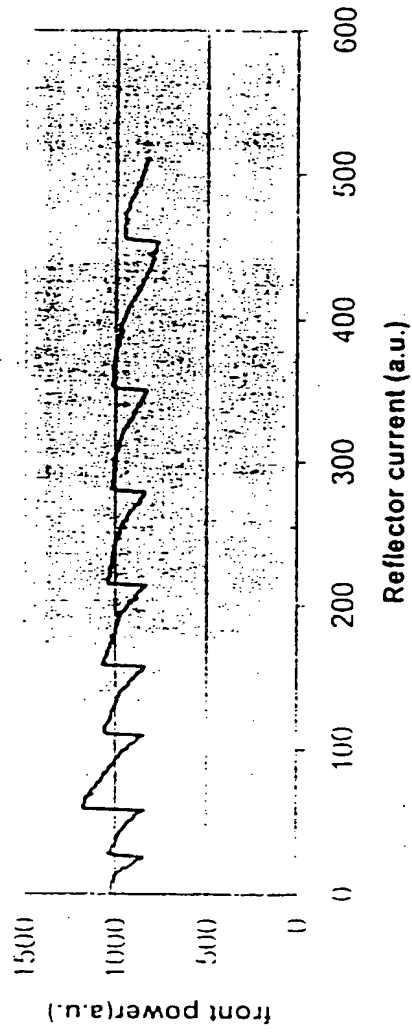


Figure 3



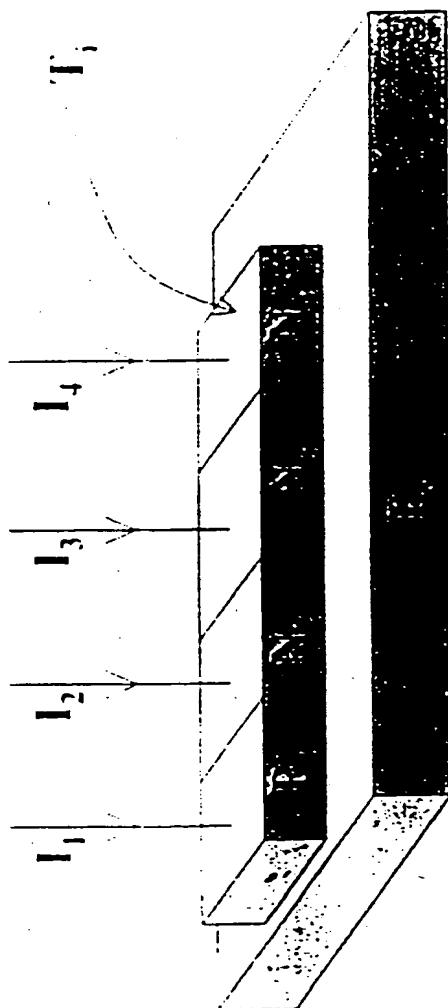


Figure 4